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SHIP-TO-SHIP TACTICAL (GROUNDWAVE RANGE) HF COMMUNICATIONS. (PERFORMANCE PREDICTIONS IN GRAPHICAL FORM)

W. H. Kelly

Naval Electronics Laboratory

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This document addresses ship-to-ship tactical hf communications (groundwave distances over seawater). It provides performance predictions in ready-to-use graphical form, and discusses transmission system factors that influence system performance. It suggests a deviation from the traditional procedure of tactical hf frequency assignment (static assignment in the 2–6-MHz band) to a more dynamic assignment procedure by making assignments based upon the tactical situation and performance predictions covering the entire hf band.

The predictions show that under certain conditions expected hf groundwave ranges will be greater in the 10–20-MHz band than at 2 MHz. Further, they indicate that atmospheric noise has considerable influence over
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performance and that shipboard hf antenna system improvement can provide significant improvement in system performance.

CONTENTS

ILLUSTRATIONS

(Minimum expected groundwave range over seawater for Link 11 type transmission)

1.0 INTRODUCTION

Recent studies relative to the role of hf in the future Naval Telecommunications System find that its primary use will be for intra-task force tactical communications. This document addresses the factors affecting ship-to-ship hf groundwave communications over an unobstructed seawater path.

2.0 DISCUSSION

It will be useful to predict groundwave performance for a typical ship-to-ship hf transmission system for determining system factors and revealing the degree to which they influence performance.

Figures 1 through 7 illustrate expected range versus frequency for groundwave hf links under the conditions listed in the notes and the assumptions described in the following paragraphs.

The main variables affecting hf transmission subsystem performance are atmospheric noise statistics and antenna pattern statistics. The typical antenna pattern appears to have a null exceeding 8 dB below average about 5% of the time. Recently designed broadband transmitting fan antennas on the smaller ships such as the PF and DLGN, on the otherhand, approach 3–4-dB nulls in the 2–6-MHz range.

When these transmit fan antennas are used as receiving antennas employing the Combination Antenna Receive Transmit System (CARTS),[1] the 3–4-dB nulls also apply to the receive system. CARTS, used with modern multicouplers, allows several simultaneous channels on one antenna with frequency separation of 5%. Without CARTS, 15% separation is required. The improvement in performance expected as a result of these better antennas is indicated in figures 2, 5, and 7.

The effect of nulls on calculated circuit range and time availability requires that a ship course change be made 5% of the time to achieve the predicted range and time availability. The use of antenna radiation patterns by the operator could determine exact course changes required. In predicting the effect of antenna nulls on performance (assuming log-normal distribution), the rule is to use the square root of the sum of the squares of the two antenna null factors:

$$\sqrt{4^2 + 4^2} = 5.6 \text{ dB}, \quad \sqrt{4^2 + 8^2} = 9 \text{ dB}, \quad \sqrt{8^2 + 8^2} = 11 \text{ dB}.$$

(Antenna degradation factor)

If the appropriate antenna degradation factor is used, the two ships will be on acceptable courses 95% of the time for the assumed conditions.

Also assumed is the 16-tone Quad PSK type of modulation, in which the power per tone is determined by the ratio of transmitter PEP rating to the number of tones to the 1.5 power, a transmit antenna system loss of 3 dB, an atmospheric-noise-limited system, and a 12-dB SNR requirement for 10^{-3} BER.

The curves of figures 1 through 7 for the 4-hour time periods indicated were determined by using the above assumptions and procedures, mean atmospheric noise values and their standard deviations,[2] and hf groundwave propagation curves.

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[1] Naval Electronics Laboratory Center Technical Report TR 1735 *Combination Antenna Receive - Transmit System*, by I. C. Olson, 8 October 1970.

[2] International Radio Consultative Committee, 10th Plenary Assembly, Geneva 1963, Report 322, *World Distribution and Characteristics of Atmospheric Radio Noise*, International Telecommunications Union, 1964

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3.0 CONCLUSIONS

3.1 HIGH NOISE AREAS OF THE WORLD*

(Refer to fig 1, 3, and 6.) For the typical 8-dB-antenna case, the best performance between 0400 and 2000 will be at the low end of the hf spectrum, with the greatest ranges achieved at 2 MHz. Between 1600 and 2000 performance will be less than the minimum 300-mile requirement.

Between 2000 and 0400 the poorest performance will be achieved at 2 MHz and essentially equal performance will be achieved between 10 and 20 MHz. During this time period the 300-mile minimum requirement will not be met at any frequency, with the best performance being approximately 150 miles in the 10–15-MHz band. For those ships having the better, 4-dB antennas, the minimum 300-mile requirement can be met, between 1600 and 2000, only by using frequencies at, or very close to, 2 MHz (with 1-kW transmitters), or by using a 5-kW transmitter for higher frequencies up to 6 MHz.

During the 2000–0400 time period, even with the better antennas and 5-kW transmitters, the minimum expected ranges are 100 miles short of the 300-mile requirement. The use of better antennas appears to raise the low end of the spectrum (2–10 MHz) to the performance of the 10–20-MHz band for a 2–20-MHz performance level of about 160 miles (see fig 6). Raising the power to 5 kW gives an additional 40 miles (not shown on fig 1).

Although it appears that between 2000 and 0400 any frequency between 2 and 20 MHz could be used with about 200-mile performance (assuming all ships have the better antennas with 5 kW of transmitter power), the use of higher frequencies (above the maximum usable frequency for 2000–4000-mile ranges) during this period would eliminate skywave interference at the low end of the spectrum. Operating groundwave circuits at higher frequencies would also clear the low end of the spectrum for any long-haul circuits that might be required.

3.2 MODERATE NOISE AREAS OF THE WORLD**

(Refer to fig 4 and 5.) For the typical 8-dB-antenna case, the best performance will be at the low end of the hf spectrum, with greatest ranges achieved at 2 MHz. Between 1600 and 0400 performance will be less than the 300-mile requirement.

In contrast to the high-noise-area case, which had the poorest performance at 2 MHz between 2000 and 0400, performance in moderate noise areas in this time frame is slightly better at 2 MHz than in the 10–20-MHz band. As shown in figure 6, communications between ships with the better antennas will meet the minimum 300-mile requirement between 1600 and 2000 when transmitting on 2 MHz (with 1-kW transmitter) and when transmitting on frequencies up to 5 MHz (with 5-kW transmitter). As also shown in figure 6, the minimum 300-mile requirement can be met between 2000 and 0400 between ships with 4-dB antennas using 5-kW transmitters operating at 2 MHz.

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*Areas of high noise that will result in severe range reduction are typically within 1000 miles of land masses between ±20° latitude. The areas within 1000 miles of the east coast of the United States and the South China coast are also high noise areas in summertime. The east coast of South America is not a high noise area, however; nor are the areas above 5° north latitude off East Africa, the Arabian Penninsula, and India.

**Typical moderate noise areas are the Mediterranean Sea and Indian Ocean.

As in the high-noise-area case, there may be times under certain operational conditions when the 10–20-MHz portion of the spectrum between 2000 and 0400 should be used. Reduced range must be accepted, advantages accrue, such as less interference at higher frequencies.

3.3 LOW NOISE AREAS OF THE WORLD*

(Refer to fig 6.) For the typical 8-dB-antenna case, the best performance will be at the low end of the hf spectrum, with greatest ranges achieved at 2 MHz. The 300-mile groundwave requirement will not be met between 2000 and 2400. As shown in figure 7, this requirement can be met between ships having the 4-dB-null antennas without the requirement for more than a 1-kW transmitter. Again, depending upon the tactical situation, the selection of frequencies between 10 and 20 MHz between 2000 and 0400 could be advantageous.

3.4 SUMMARY

The above analysis is for hf groundwave only, covering four geographical areas in one season (summertime). Additional predictions for other areas and seasons could be made. Those discussed were chosen as representative of the low, moderate, and high noise areas in which the Navy operates. A communications planner, knowing the kind of noise area in which his force will operate, could use these data to suit the tactical situation. For example, during the day the lower frequencies will provide the best performance, while at night, especially in high and moderate noise areas, higher frequencies may be desirable. Proper choice of frequencies for intra-task force (groundwave range) communications, as a general rule, above a 3000-mile MUF at night and below a 3000-mile LUF during the day in mid-ocean could provide many tactical benefits (for example, make it difficult to DF task forces or jam tactical hf links from long distances; and reduce congestion in the hf band by maintaining greater separation between long-haul and tactical circuits).

4.0 RECOMMENDATIONS

- Tests should be conducted to determine the validity of the predictions; upon conclusion of the tests, if results are favorable, communications planners should be provided with information necessary to utilize the predictions.
- Hf antenna designs for new ships should establish the goal of groundwave radiation patterns in the 2–20-MHz band such that the nulls are no worse than 4 dB below average 95% of the time. This design goal should extend to influencing the configuration of topside structure.
- Future system design should consider provision of hf tandem switching as an approach extending the ranges of tactical hf at the higher frequencies.

*Low noise areas are typically in the regions above 60°N or below 60°S latitudes, and mid and eastern Pacific.

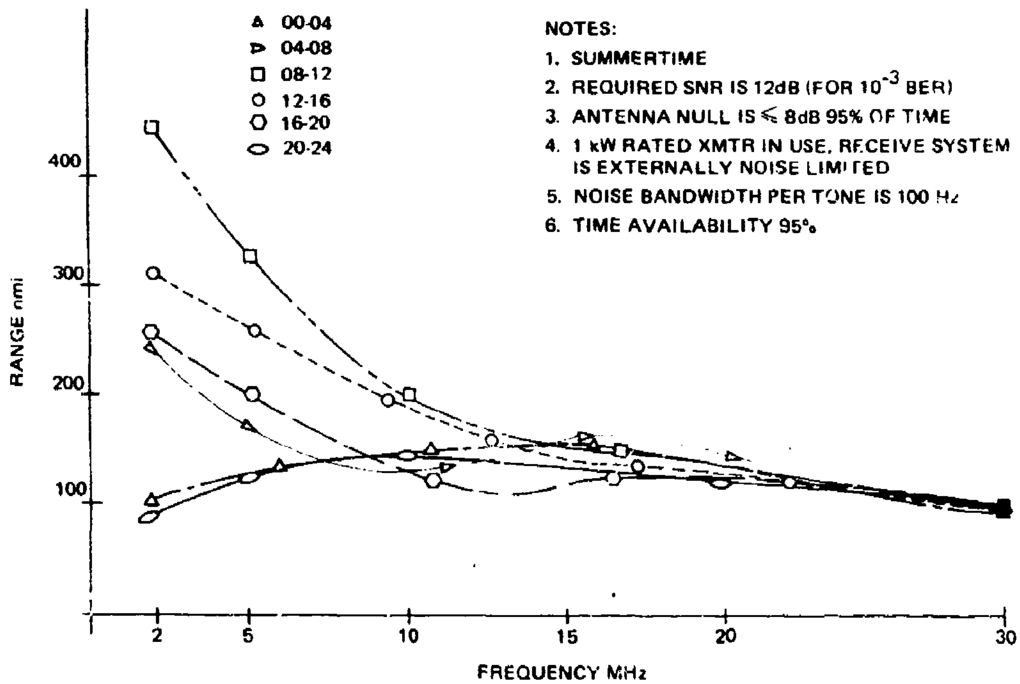

Figure 1. Minimum expected groundwave range over seawater for Link 11 type transmission, South China Sea.

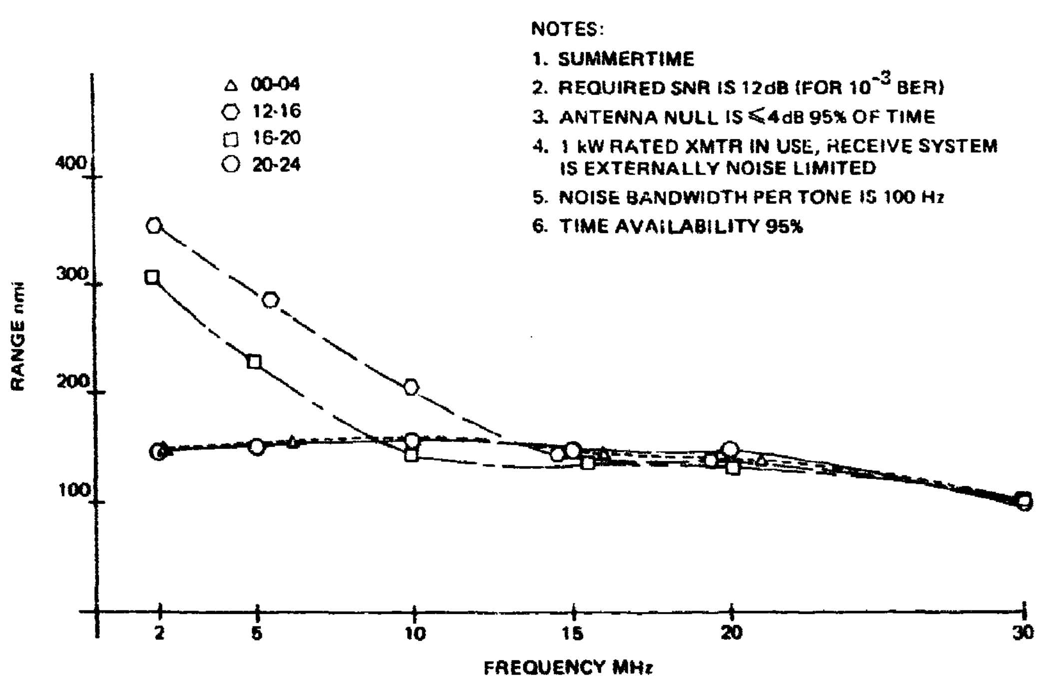

Figure 2. Minimum expected groundwave range over seawater for Link 11 type transmission, South China Sea (improved antenna).

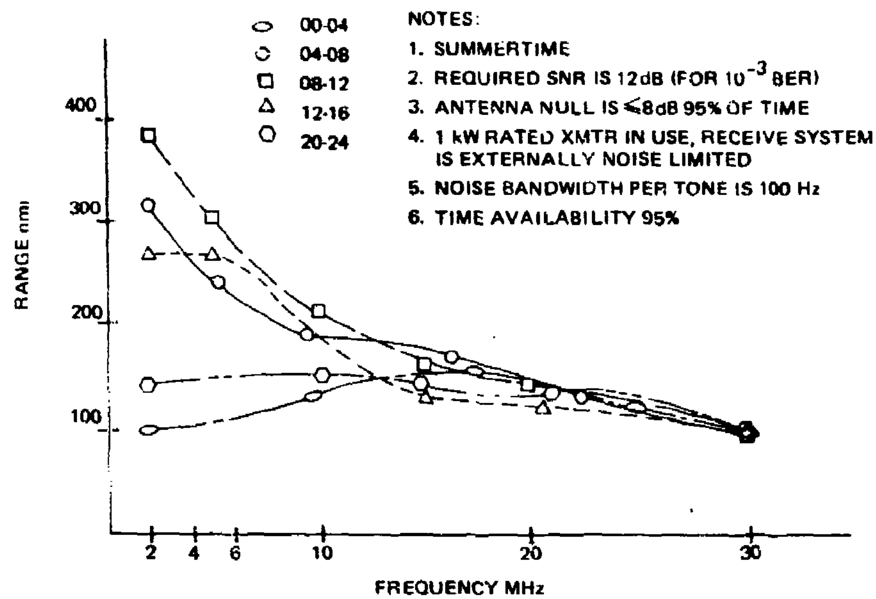

Figure 3. Minimum expected groundwave range over seawater for Link 11 type transmission, Virginia Capes area.

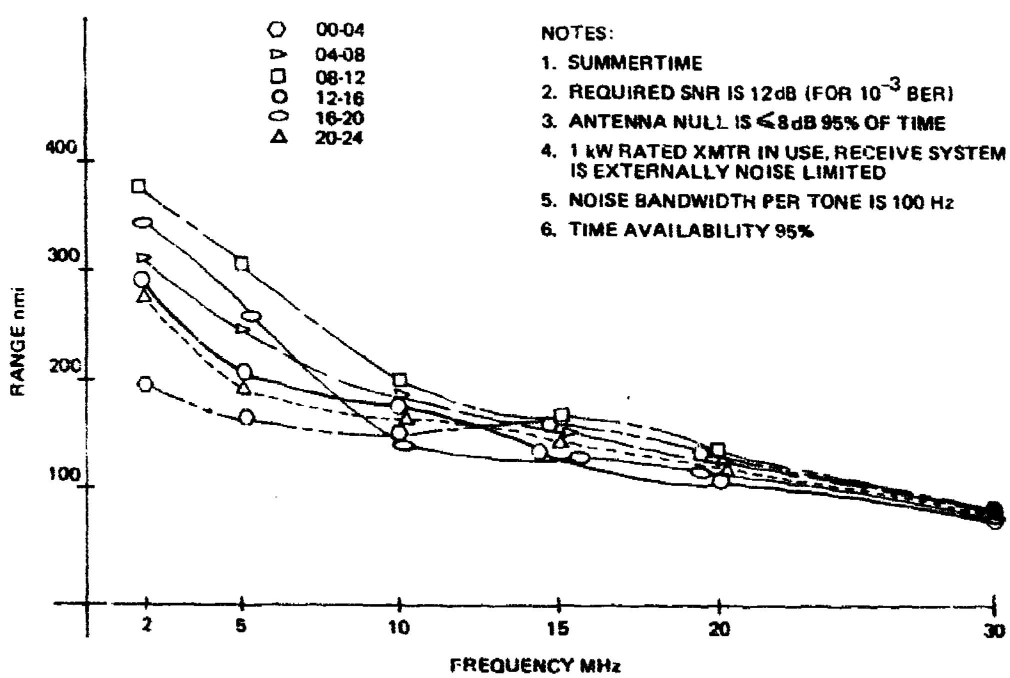

Figure 4. Minimum expected groundwave range over seawater for Link 11 type transmission, Central Mediterranean.

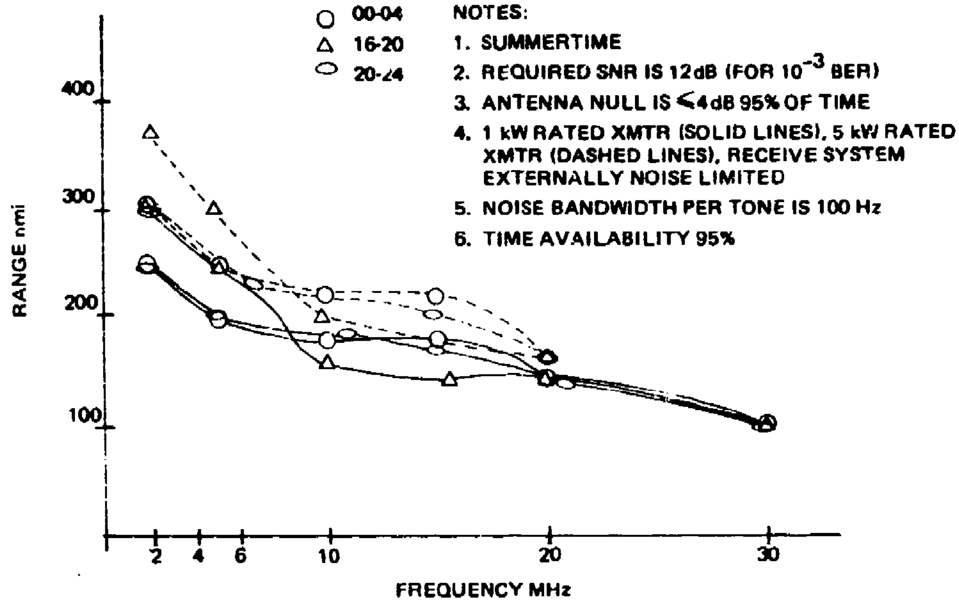

Figure 5. Minimum expected groundwave range over seawater for Link 11 type transmission, Central Mediterranean (improved antenna).

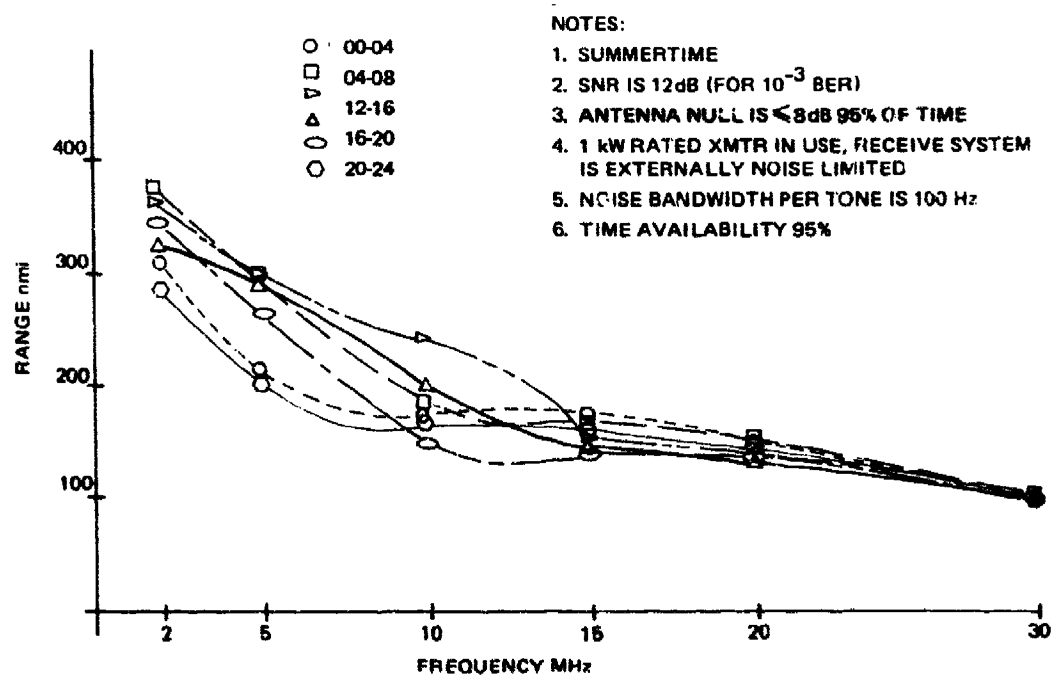

Figure 6. Minimum expected groundwave range over seawater for Link 11 type transmission, Southern California area.

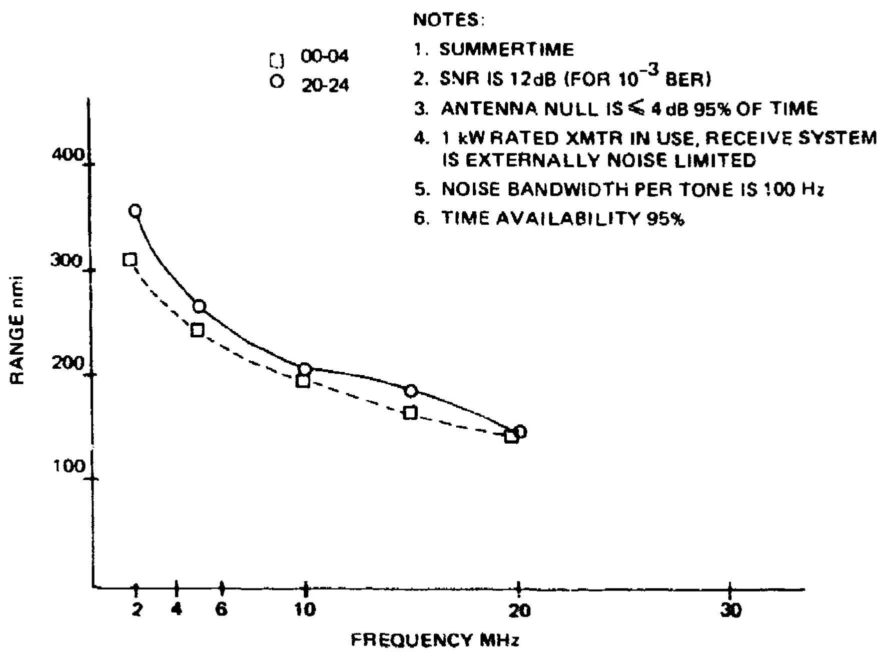

Figure 7. Minimum expected groundwave range over seawater for Link 11 type transmission, Southern California area (improved antenna).